NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

"TROPOPLOT"

An Improved Fortran Computer Program for Prediction of Long-Term Median Tropospheric Radio Transmission Loss Over Irregular Terrain

by

James Michael Callaghan

Thesis Advisor: R. W. Adler

June 1973

Thesis
C1885

Approved for public release; distribution unlimited.

LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIF. 93940

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

"TROPOPLOT"

An Improved Fortran Computer Program for Prediction of Long-Term Median Tropospheric Radio Transmission Loss Over Irregular Terrain

by

James Michael Callaghan

Thesis Advisor: R. W. Adler

June 1973

Approved for public release; distribution unlimited.

"TROPCPLCT"

AN IMPROVED FORTRAN COMPUTER PROGRAM FOR PREDICTION OF LONG-TERM MEDIAN TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN

BY

JAMES M. CALLAGHAN LIEUTENANT, UNITED STATES NAVY

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

FROM THE

NAVAL POSTGRADUATE SCHOOL

LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIF. 93940

ABSTRACT

THE OBJECT OF THIS STUDY WAS TO DEVELOP A HIGHLY ACCURATE LONG RANGE COMPUTER PROGRAM TO DO PREDICTIONS OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN. THE COMPUTER PROGRAM WAS TO BE EASY TO USE WITH AN INPUT AND OUTPUT DATA FORMAT SUCH THAT THE USER COULD USE THE PROGRAM WITH LITTLE PRIOR INSTRUCTION. SIGNAL STRENGTH CALCULATION CAPABILITY WAS ALSO TO BE INCLUDED IN THE PROGRAM. THE BASIS FOR THE PROGRAM THEORY WAS ESSA RESEARCH REPORT NUMBER ERL 67-ITS 67, "PREDICTION OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN."

TABLE OF CONTENTS

I. INTRODUCTION ---------- 4

II. COMPUTER PROGRAMMED TRANSMISSION THEORY ---------- 8

III. USING THE MODIFIED ERL PROGRAM ---------- 13

PROGRAM OUTPUT EXAMPLE ---------- 19

COMPUTER PROGRAM LISTING ---------- 23

INITIAL DISTRIBUTION LIST ---------- 43

FORM DD 1473 ---------- 44

I. INTRODUCTION

WHEN RF POWER RADIATES FROM A TRANSMITTING ANTENNA IT IS SPREAD OVER A WIDE AREA. THUS, THE POWER AVAILABLE AT THE RECEIVING ANTENNAS IS ONLY A SMALL PART OF THE RADIATED POWER.

THE LOSS DUE TO TRANSMISSION BETWEEN THE TRANSMITTING AND RECEIVING ANTENNAS DETERMINES IF THE RECEIVED SIGNAL WILL BE USEFUL. POOR QUALITY OR POOR RELIABILITY CAN RESULT IF THE MAXIMUM ALLOWABLE TRANSMISSION LOSS FOR THE RADIO SYSTEM IS EXCEEDED. ON PATHS THAT APPROXIMATE THE IDEAL FREE SPACE OR PLANE EARTH, FAIRLY GOOD PREDICTIONS OF TRANSMISSION LOSS CAN BE MADE. THE ACTUAL PATH GEOMETRY OR ATMOSPHERIC CONDITIONS IN THE REAL WORLD DIFFER SO MUCH FROM THE BASIC ASSUMPTIONS THAT ABSOLUTE ACCURACY CANNOT BE EXPECTED.

THERE IS GREAT INTEREST TODAY IN RADIO WAVE PROPAGATION BEHAVIOR IN THE TROPOSPHERE, WHICH IS THE LAYER OF THE ATMOSPHERE WHERE CLOUDS CAN EXIST. ITS UPPER LIMIT, CALLED THE TROPOPAUSE, IS AT A HEIGHT OF ABOUT SIX KILOMETERS AT THE POLES AND ABOUT EIGHTEEN KILOMETERS AT THE EQUATOR.

MANY COMPLEX FORMULAS HAVE BEEN DERIVED TO MAKE BETTER PREDICTIONS OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN. THESE EQUATIONS HAVE BEEN PUT TOGETHER IN ORDER TO ESTABLISH A PROPAGATION THEORY. THE THEORY HAS BEEN TESTED AGAINST A LARGE NUMBER OF PROPAGATION MEASUREMENTS AND HAS HELD UP QUITE WELL. THE MORE ACCURATE THE THEORY THE MORE EQUATIONS NEEDED.

IN THIS DAY AND AGE ACCURATE THEORY REQUIRES A LOT OF TIME TO SOLVE MANY COMPLEX EQUATIONS. A COMPUTER IS NEEDED TO COMBINE THE NUMEROUS EQUATIONS AND SOLVE THEM IN A SHORT AMOUNT OF TIME GIVEN CERTAIN NEEDED INFORMATION. BEFORE A COMPUTER CAN BE USED IT MUST HAVE A SOFTWARE PROGRAM WHICH COMBINES THESE WELL ESTABLISHED EQUATIONS IN AN ORDERLY FASHION IN ORDER TO ARRIVE AT A NUMERICAL SOLUTION.

IN JULY 1968 ESSA RESEARCH LABORATORIES PUBLISHED A TECHNICAL REPORT TITLED: PREDICTION OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN- A COMPUTER METHOD- 1968 BY A. G. LONGLEY AND P. L. RICE. THE REPORT NUMBER WAS ERL 79-ITS 67.

THE ESSA REPORT CONTAINED A COMPUTER METHOD FOR PREDICTING LONG TERM MEDIAN TRANSMISSION LOSS OVER IRREGULAR TERRAIN. THE METHOD WAS APPLICABLE FOR RADIO FREQUENCIES ABOVE 20 MHZ AND MAY BE USED EITHER WITH DETAILED TERRAIN PROFILES FOR ACTUAL PATHS OR WITH PROFILES THAT ARE

REPRESENTATIVE OF MEDIAN TERRAIN CHARACTERISTICS FOR A GIVEN AREA. ESTIMATES OF VARIABILITY IN TIME AND WITH LOCATION AND A METHOD FOR COMPUTING SERVICE PROBABILITY WERE INCLUDED.

THE PROGRAM GIVEN IN THE REPORT WAS VERY LIMITED IN ITS DIRECT APPLICATIONS. IT WAS WRITTEN FOR USE ON A CONTROL DATA CORPORATION COMPUTER, WHICH MADE IT UNUSEABLE FOR AN IBM COMPUTER. THE PROGRAM, AS WRITTEN, COULD NOT READ IN DATA FROM A CARD SOURCE. THE WORK INVOLVED IN THIS THESIS USES NO NEW PROPAGATION THEORY, HOWEVER, IT DOES COMPLETELY REWORK THE SOFTWARE COMPUTER PROGRAM IN THE REPORT IN ORDER TO MAKE IT MORE EASY TO USE, MORE FLEXIBLE AND ACCURATE, AND INCLUDES IN THE OUTPUT, A GRAPHICAL PLOT. IT ALSO RETURNS SIGNAL STRENGTH.

THE PROPAGATION PROGRAM IS INTENDED FOR USE WITHIN THE FOLLOWING RANGES:

PARAMETER	RANGE	
FREQUENCY	20 TO 40,000	MHZ
ANTENNA HEIGHTS	0.5 TO 3,000	M
DISTANCE	1 TO 2,000	KM
SURFACE REFRACTIVITY	250 TO 400	N-UNITS

THE ANGLE OF ELEVATION OF EACH HORIZON RAY ABOVE THE HORIZONTAL SHOULD NOT EXCEED 12 DEGREES, AND THE DISTANCE FROM EACH ANTENNA TO ITS HORIZON SHOULD NOT BE LESS THAN ONE TENTH, OR MORE THAN THREE TIMES, THE CORRESPONDING SMOOTH-EARTH DISTANCE.

II. COMPUTER PROGRAMMED TRANSMISSION THEORY

BEFORE GOING INTO THE PARTICULAR ASPECTS OF HOW TO USE THE PROGRAM, A BRIEF GENERAL OUTLINE OF THE THEORY USED IN THE ERL 79 - ITS 67 REPORT WILL BE GIVEN.

RADIO TRANSMISSION LOSS IN TROPOSPHERIC PROPAGATION DEPENDS ON CHARACTERISTICS OF THE ATMOSPHERE AND TERRAIN. THE REFRACTIVE INDEX GRADIENT NEAR THE EARTH'S SURFACE IS THE MOST IMPORTANT ATMOSPHERIC PARAMETER FOR PREDICTING A LONG TERM MEDIAN REFERENCE VALUE OF TRANSMISSION LOSS. THIS SURFACE GRADIENT LARGELY DETERMINES THE BENDING OF A RADIO RAY AS IT PASSES THROUGH THE ATMOSPHERE. RAYS MAY BE REPRESENTED AS STRAIGHT LINES, WITHIN THE FIRST KILOMETER ABOVE THE EARTH'S SURFACE, IF AN "EFFECTIVE EARTH RADIUS", IS DEFINED AS A REFRACTIVITY.

FOR THE CALCULATION OF THE LONG-TERM REFERENCE VALUE, THE MINIMUM MEAN VALUE IS PICKED TO CHARACTERIZE AVERAGE ATMOSPHERIC CONDITIONS. THE MINIMUM MONTHLY MEAN VALUE OF SURFACE REFRACTIVITY IS OBTAINED FROM MEASUREMENTS FROM SUCH MAPS AS BEAN, HORN, AND OZANICH (1960), "11 CLIMATIC CHARTS AND DATA OF THE RADIO REFRACTIVE INDEX, FOR THE UNITED STATES AND THE WORLD," NBS MONOGRAPH NO. 22 (U.S. GOVERNMENT

PRINTING OFFICE, WASHINGTON, D. C.)

ATMOSPHERIC EFFECTS, SUCH AS CHANGES IN THE REFRACTIVE INDEX, CHANGES IN THE AMOUNT OF TURBULENCE OR STRATIFICATION, ABSORPTION BY OXYGEN, WATER VAPOR, CLOUDS, AND PRECIPITATION, ARE ALLOWED FOR BY EMPIRICAL ADJUSTMENTS.

PROGRAM CALCULATIONS ARE INCLUDED TO HANDLE EFFECTS OF TROPOSPHERIC SCATTER AND DIFFRACTION DUE TO KNIFE EDGES, ROUGH TERRAIN, AND SMOOTH SPHERICAL EARTH. SHORT AND LONG TERM FADING ADJUSTMENTS TO MEDIAN ATTENUATIONS ARE ACCOUNTED FOR BY DERIVING FACTORS WHICH COME FROM AVERAGING FADING MEASUREMENTS MADE ON MANY DIFFERENT TROPOSPHERIC COMMUNICATIONS SYSTEMS.

IF DETAILED PROFILES ARE AVAILABLE FOR SPECIFIC PATHS, TRANSMISSION LOSS CAN BE CALCULATED. TO CHARACTERIZE TERRAIN, PROFILES MAY BE READ AT REGULAR INTERVALS IN BOTH N-S AND E-W DIRECTIONS OR ACTUAL OR PROPOSED TERRAIN CONDITIONS MAY BE COMBINED TO PROVIDE A SINGLE SET OF PROFILES FOR WHICH AN ESTIMATE OF MEDIAN PROPAGATION CONDITIONS IS DESIRED. THE INTERDECILE RANGE OF TERRAIN HEIGHTS ABOVE AND BELOW A FIXED LINE FITTED TO ELEVATIONS ABOVE SEA LEVEL, IS CALCULATED AT FIXED DISTANCES. USUALLY MEDIAN VALUES OF THE INTERDECILE RANGE INCREASE WITH PATH LENGTH TO AN ASYMPTOTIC VALUE WHICH IS USED TO CHARACTERIZE THE TERRAIN.

TYPE OF TERRAIN	ASYMPTOTIC VALUE (METERS) OF INTERDECILE HEIGHT
VERY SMOOTH PLAINS OR WATER	0-5
SMOOTH PLAINS	5-20
SLIGHTLY ROLLING PLAINS	20-40
ROLLING PLAINS	40-80
HILLS	80-150
MOUNTAINS	150-300
RUGGED MOUNTAINS	300-700
EXTREMELY RUGGED MOUNTAINS	> 700

TO CALCULATE REFERENCE VALUES OF TRANSMISSION LOSS FOR A SPECIFIC APPLICATION, A MINIMUM OF FOUR ESSENTIAL PARAMETERS MUST BE SUPPLIED. THESE FOUR PARAMETERS ARE FREQUENCY IN MEGAHERTZ, THE TRANSMITTING AND RECEIVING ANTENNA HEIGHTS ABOVE GROUND IN METERS, AND THE PATH DISTANCE IN KILOMETERS. PATH PARAMETERS SUCH AS HORIZON DISTANCES AND ELEVATION ANGLES, MAY ALSO BE DERIVED FROM THE PRECEDING PARAMETERS.

THE CONDUCTIVITY OF THE EARTH'S SURFACE AND ITS

PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT ENTER INTO THE CALCULATIONS FOR LINE-OF-SIGHT AND DIFFRACTION ATTENUATION. IF THE VALUES OF THESE GROUND CONSTANTS ARE NOT KNOWN, THE FOLLOWING TABLE VALUES MAY BE ASSUMED:

TYPE OF SURFACE	CONDUCTIVITY(MHO/M)	DIELECTRIC CONSTANT
POOR GROUND	0.001	4
AVERAGE GROUND	0.005	15
GOOD GROUND	0.020	25
SEA WATER	5.000	81
FRESH WATER	0.010	81

AT SUFFICIENTLY LOW FREQUENCIES, THE EFFECT OF THE CONDUCTIVITY DOMINATES WHILE AT SUFFICIENTLY HIGH FREQUENCIES, THE DIELECTRIC CONSTANT DOMINATES. THE TRANSITION OCCURS BETWEEN 300 TO 3000 MEGAHERTZ FOR OVERSEA TRANSMISSION, WHILE OVER "AVERAGE" GROUND THE TRANSITION OCCURS BETWEEN 5 TO 50 MEGAHERTZ. FOR PROPAGATION OVER IRREGULAR TERRAIN, AT FREQUENCIES ABOVE 100 MEGAHERTZ, WITH ANTENNAS MORE THAN FIVE METERS ABOVE GROUND, THE EFFECTS OF THE GROUND CONSTANTS ARE SLIGHT AND THE RESULT, FOR VERTICAL AND HORIZONTAL POLARIZATION IS NEARLY THE SAME. UNDER THESE

CONDITIONS THE METHOD IS SIMPLIFIED BY ASSUMING THE MAGNITUDE OF THE THEORETICAL REFLECTION COEFFICIENT EQUAL TO 0.95 AND THE PHASE SHIFT EQUAL TO ZERO. FOR MANY APPLICATIONS THIS RESULTS IN AN ESTIMATE OF THE EFFECTIVE REFLECTION COEFFICIENT OF 0.9, AND THE ATTENUATION MAY BE CALCULATED DIRECTLY. THESE APPROXIMATIONS ARE NOT APPLICABLE FOR TRANSMISSION OVER THE SEA.

TO SUMMARIZE, THE PARAMETERS REQUIRED FOR COMPUTING REFERENCE VALUES OF TRANSMISSION, OR THE CORRESPONDING ATTENUATION BELOW FREE SPACE ARE: FREQUENCY IN MEGAHERTZ, DISTANCE IN KILOMETERS, ANTENNA HEIGHTS ABOVE GROUND IN METERS, ESTIMATES OF SURFACE REFRACTIVITY, THE TERRAIN IRREGULARITY IN METERS, THE CONDUCTIVITY IN MHOS/METER, AND THE RELATIVE DIELECTRIC CONSTANT OF THE GROUND.

III. USING THE MODIFIED ERL PROGRAM

THE MODIFIED ERL COMPUTER PROGRAM WAS WRITTEN FOR EASE OF OUTPUT READING, ACCURACY, AND EASE OF USER DATA INPUT. THE PROGRAM LISTING CONTAINS INSTRUCTIONS FOR DATA INPUT. THIS ALLOWS THE PROGRAM TO BE USED WITHOUT EXTERNAL PROGRAM INSTRUCTIONS.

THERE ARE ONLY FOUR DATA INPUT CARDS USED IN THIS PROGRAM. IN MANY CASES ONLY TWO DATA INPUT CARDS ARE USED. THIS PROGRAM PREDICTS LONG-TERM MEDIAN RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN. THUS, THE USER SHOULD NOT EXPECT A SHORT TERM LOSS PREDICTION OUTPUT EVEN THOUGH THE INPUT DATA IS OF A SHORT TERM NATURE.

INTEGER NUMBERS MUST BE PUNCHED SO THAT THE NUMBER ENDS IN THE LAST COLUMN NUMBER FIELD. IF SPACES ARE LEFT AT THE END OF THE FIELD THEY WILL BE READ AS ZEROS, IN EFFECT MULTIPLYING THE DESIRED NUMBER BY A POWER OF TEN. REAL NUMBERS ARE PUNCHED AS A STRING OF DIGITS CONTAINING A DECIMAL, AND MAY BE PUNCHED ANYWHERE IN THEIR FIELD.

FIRST DATA CARD:

THE FIRST DATA CARD CONTAINS DATA COVERING CODE NUMBERS FOR TYPE OF TERRAIN, DB LOSS INFORMATION DESIRED, AND DISTANCE BETWEEN ANTENNAS. THIS CARD MUST BE INCLUDED IN THE DATA CARD SET.

COLUMN: 01-10 "TYPE OF TERRAIN" -INTEGER
- CODE: 1 COLORADO PLAINS (OMIT THIRD DATA CARD)
- CODE: 2 COLORADO MOUNTAINS (OMIT THIRD DATA CARD)
- CODE: 3 OHIO (OMIT THIRD DATA CARD)
- CODE: 4 USER TERRAIN DATA WITHOUT DATA SUPPRESSION
- CODE: 5 USER TERRAIN DATA NO "OUTPUT PARAMETERS" PRINTED

COLUMN: 11-20 "DB LOSS" -INTEGER
- CODE: 0 NO DB DATA DESIRED (OMIT SECOND DATA CARD)
- CODE: 1 DB DATA DESIRED

COLUMN: 21-30 "DISTANCE BETWEEN ANTENNAS" -REAL (1-2,000) K-METERS

SECOND DATA CARD:

THE SECOND DATA CARD CONTAINS DATA COVERING SIGNAL STRENGTH DB CALCULATIONS AND OUTPUT. IF COLUMN 11-20 OF THE FIRST DATA CARD CONTAINS A "0" THE SECOND DATA CARD IS OMITTED.

COLUMN: 01-10 "TX POWER OUT" (WATTS) POSITIVE REAL NUMBER

COLUMN: 11-20 "TX ANTENNA GAIN" (DB) POSITIVE REAL NUMBER

COLUMN: 21-30 "RX ANTENNA GAIN" (DB) POSITIVE REAL NUMBER

COLUMN: 31-40 "TRANSMITTER LINE LOSS" (DB)
POSITIVE REAL NUMBER

COLUMN: 41-50 "REQUIRED RECEIVER LINE LOSS" (DB)
POSITIVE REAL NUMBER

COLUMN: 51-60 "RECEIVER INPUT LEVEL" (DBM)
POSITIVE REAL NUMBER

THIRD DATA CARD:

THE THIRD DATA CARD CONTAINS DATA COVERING SURFACE REFRACTIVITY, SURFACE CONDUCTIVITY, PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT, AND INTERDECILE RANGE. THIS CARD IS NOT USED IF COLUMN 01-10 OF THE FIRST DATA CARD CONTAINS A "1", "2", OR "3".

COLUMN: 01-10 "SURFACE REFRACTIVITY" -INTEGER
(250-400) N-UNITS NS

COLUMN: 11-20 "SURFACE CONDUCTIVITY" (MHOS/METER)

COLUMN: 21-30 "PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT"

COLUMN: 31-40 "INTERDECILE RANGE"
DELTA-H

FORTH DATA CARD:

THE FORTH DATA CARD CONTAINS DATA COVERING ANTENNA POLARIZATION, FREQUENCY, AND ANTENNA HEIGHT OF THE TRANSMITTING AND RECEIVING ANTENNA. THIS CARD MUST BE INCLUDED IN THE DATA CARD SET.

COLUMN: 01-10 "ANTENNA POLARIZATION" -REAL

CODE: 01.00 VERTICAL POLARIZATION

CODE: -1.00 HORIZONTAL POLARIZATION

COLUMN: 11-20 "FREQUENCY" (MEGAHERTZ)
(20-40,000)

COLUMN: 21-30 "STRUCTURAL ANTENNA HEIGHT OF TRANSMITTING ANTENNA" -REAL
(0.5-3000.0) METERS

COLUMN:31-40 "STRUCTURAL ANTENNA HEIGHT OF RECEIVING ANTENNA" -REAL

(0.5-3000.0) METERS

DATA CARD ONE CONTAINS CODES FOR THE USE OF COLORADO PLAINS, COLORADO MOUNTAINS, OR OHIO TERRAIN PARAMETERS. THESE PARAMETER OPTIONS WERE PUT IN THE PROGRAM SINCE THEY OFFER WELL-USED GENERAL TYPES OF DIFFERING TERRAIN. FOR EXAMPLE, IF THE USER DOES NOT HAVE ANY PARTICULAR TERRAIN CONSTANTS TO USE AND WANTED TO CHECK HIS DATA USING A MOUNTAINOUS TERRAIN, HE WOULD USE THE CODE IN THE FIRST DATA CARD FOR COLORADO MOUNTAIN TERRAIN. THE FOLLOWING TABLE GIVES THE CONSTANTS USED IN THE PROGRAM FOR THE PRESET TERRAINS:

TERRAIN	SURFACE REFRACTIVITY	SURFACE CONDUCTIVITY	DIELECTRIC CONSTANT	DH DELTA-H
OHIO	312.0	0.005	15.0	90.0
COLORADO PL.	290.0	0.005	15.0	90.0
COLORADO MT.	290.0	0.005	15.0	650.0

EXAMPLE PROGRAM DATA CARD SETUP

THE FOLLOWING TWO EXAMPLES SHOULD GIVE THE USER A BETTER GRASP OF SETTING UP THE DATA CARDS FOR THE MODIFIED ERL PROGRAM.

EXAMPLE ONE:

THE USER WANTS TO USE COLORADO PLAINS TYPE TERRAIN DATA. HE ALSO WANTS TO USE THE FOLLOWING DATA:

DB LOSS	YES
FREQUENCY	450.00 MEG-HERTZ
TX POWER OUT	8.00 WATTS
TX ANTENNA GAIN	10.00 DB
RX ANTENNA GAIN	13.50 DB
RECEIVER LINE LOSS	2.00 DB
ANTENNA POLARIZATION	VERTICAL
TRANSMISSION LINE LOSS	2.00 DB
DISTANCE BETWEEN ANTENNAS	242.0 K-METERS
REQUIRED RECEIVER INPUT LEVEL	-113.00 DBM
STRUCTURAL ANTENNA HEIGHT OF TX ANTENNA	4.00 METERS
STRUCTURAL ANTENNA HEIGHT OF RX ANTENNA	40.00 METERS

EXAMPLE TWO:

THE USER WANTS TO USE HIS OWN TERRAIN DATA AND DOES NOT WANT TO USE THE SIGNAL STRENGTH PROGRAM OPTION. THE USER DESIRES TO USE THE FOLLOWING DATA:

DB LOSS	NO
DELTA-H	750.00 METERS
FREQUENCY	100.00 MEG-HERTZ
DIELECTRIC CONSTANT	15.00
ANTENNA POLARIZATION	HORIZONTAL
SURFACE CONDUCTIVITY	0.005 MHOS/METER
SURFACE REFRACTIVITY	350.00 N-UNITS
DISTANCE BETWEEN ANTENNAS	300.00 K-METERS
STRUCTURAL ANTENNA HEIGHT OF TX ANTENNA	37.05 METERS
STRUCTURAL ANTENNA HEIGHT OF RX ANTENNA	72.08 METERS

TABLE OF THE EXAMPLE DATA CARD SETTINGS

CARDS AND COLUMNS	EXAMPLE ONE	EXAMPLE TWO
FIRST DATA CARD		
C1-10	1	4
11-20	1	0
21-30	242.0	300.00
SECOND DATA CARD		(NOT USED)
C1-10	8.0	-------
11-20	10.0	-------
21-30	13.5	-------
31-40	2.0	-------
41-50	2.0	-------
51-60	113.0	-------
THIRD DATA CARD	(NOT USED)	
C1-10	-------	350.00
11-20	-------	0.005
21-30	-------	15.00
31-40	-------	750.00
FOURTH DATA CARD		
C1-10	1.0	-1.0
11-20	450.0	100.00
21-30	4.0	37.05
31-40	40.0	72.08

NOTE: ALL INTEGER VALUES MUST BE RIGHT JUSTIFIED IN THEIR RESPECTIVE COLUMN FIELDS.

THE NEXT SECTION, STARTING ON PAGE 19, CONTAINS THE SAMPLE OUTPUT DATA FORMATS. THE PROGRAM LISTING STARTS ON PAGE 23.

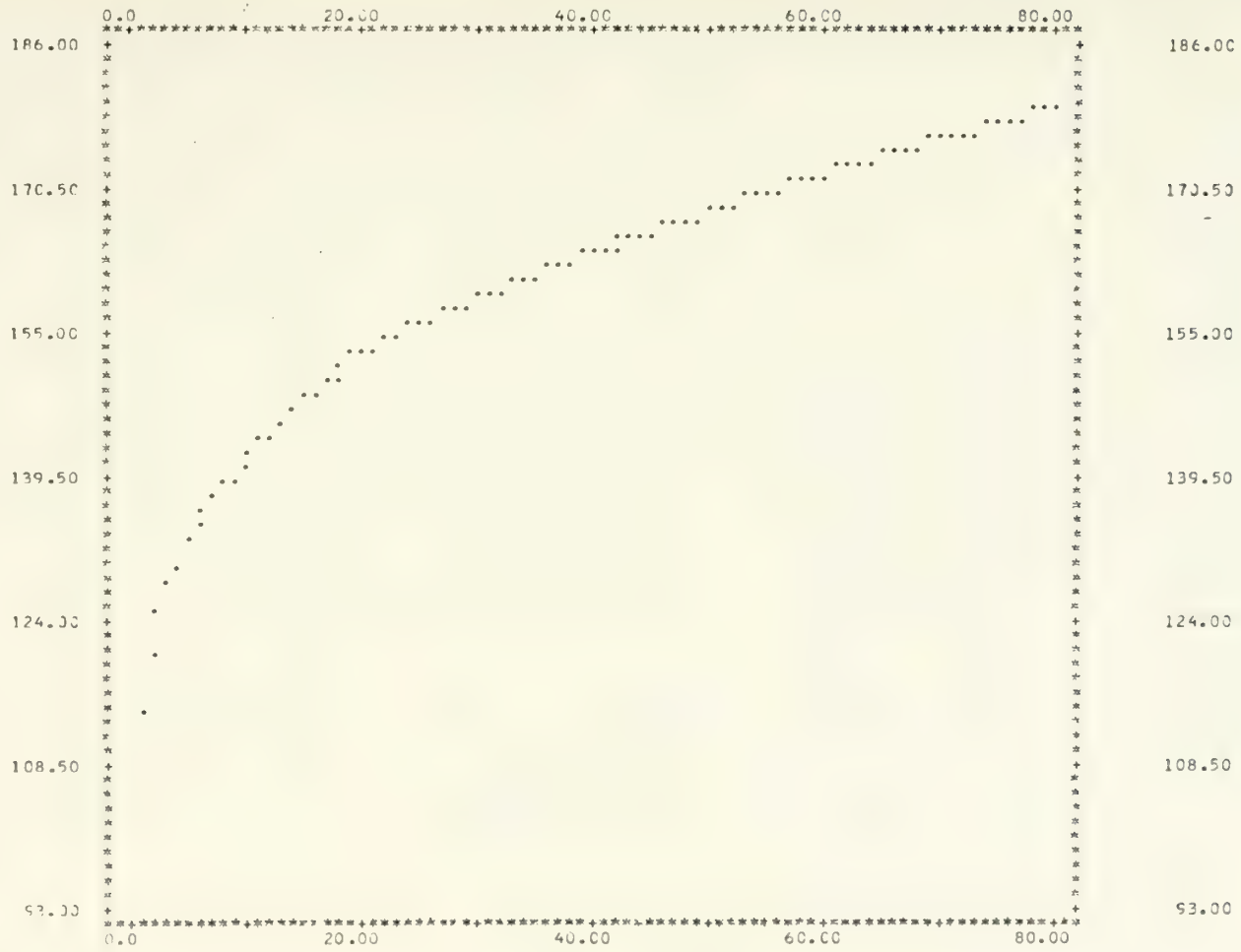
--- USER TERRAIN DATA ---

FREQUENCY OF SIGNAL -F- (MEG-HERTZ) · 100.00000

DISTANCE (KM)	TRANS-LOSS (DB)	DISTANCE (KM)	TRANS-LOSS (DB)	DISTANCE (KM)	TRANS-LOSS (DB)	DISTANCE (KM)	TRANS-LOSS (DB)	DISTANCE (KM)	TRANS-LOSS (DB)
0.8000	114.41	16.8000	150.25	32.8000	160.75	48.8000	168.12	64.8000	174.50
1.6000	121.11	17.6000	151.09	33.6000	161.16	49.6000	168.46	65.6000	174.80
2.4000	125.19	18.4000	151.90	34.4000	161.56	50.4000	168.79	66.4000	175.10
3.2000	128.21	19.2000	152.70	35.2000	161.95	51.2000	169.13	67.2000	175.40
4.0000	130.65	20.0000	153.32	36.0000	162.34	52.0000	169.46	68.0000	175.70
4.8000	132.71	20.8000	153.86	36.8000	162.73	52.8000	169.78	68.8000	176.00
5.6000	134.52	21.6000	154.38	37.6000	163.11	53.6000	170.11	69.6000	176.30
6.4000	136.15	22.4000	154.89	38.4000	163.49	54.4000	170.44	70.4000	176.59
7.2000	137.63	23.2000	155.39	39.2000	163.87	55.2000	170.76	71.2000	176.89
8.0000	138.99	24.0000	155.88	40.0000	164.24	56.0000	171.08	72.0000	177.18
8.8000	140.27	24.8000	156.36	40.8000	164.61	56.8000	171.40	72.8000	177.47
9.6000	141.47	25.6000	156.84	41.6000	164.97	57.6000	171.72	73.6000	177.76
10.4000	142.61	26.4000	157.30	42.4000	165.33	58.4000	172.03	74.4000	178.05
11.2000	143.69	27.2000	157.75	43.2000	165.69	59.2000	172.34	75.2000	178.34
12.0000	144.73	28.0000	158.20	44.0000	166.05	60.0000	172.66	76.0000	178.63
12.8000	145.73	28.8000	158.64	44.8000	166.40	60.8000	172.97	76.8000	178.91
13.6000	146.69	29.6000	159.08	45.6000	166.75	61.6000	173.28	77.6000	179.20
14.4000	147.62	30.4000	159.50	46.4000	167.09	62.4000	173.59	78.4000	179.49
15.2000	148.52	31.2000	159.93	47.2000	167.44	63.2000	173.89	79.2000	179.77
16.0000	149.40	32.0000	160.34	48.0000	167.78	64.0000	174.20	80.0000	180.05

PLOT OF TRANS.-LOSS VERSUS DISTANCE

** NOTE ** TO FIND SIGNAL STRENGTH FROM GRAPH, SUBTRACT TRANS.-LOSS FROM 66.00



TRANS-LOSS (DB)

DISTANCE (K-METERS)

--- SIGNAL STRENGTH VERSUS DISTANCE FOR GIVEN SYSTEM PARAMETERS ---

DISTANCE (KM)	SIG-STRENGTH (DBM)	DISTANCE (KM)	SIG-STRENGTH (DBM)	DISTANCE (KM)	SIG-STRENGTH (DBM)	DISTANCE (KM)	SIG-STRENGTH (DBM)	DISTANCE (KM)	SIG-STRENGTH (DBM)
0.8000----	-48.41	16.8000----	-84.25	32.8000----	-94.75	48.8000----	-102.12	64.8000----	-108.50
1.6000----	-55.11	17.6000----	-85.09	33.6000----	-95.16	49.6000----	-102.46	65.6000----	-108.80
2.4000----	-59.19	18.4000----	-85.90	34.4000----	-95.56	50.4000----	-102.79	66.4000----	-109.10
3.2000----	-62.21	19.2000----	-86.70	35.2000----	-95.95	51.2000----	-103.13	67.2000----	-109.40
4.0000----	-64.65	20.0000----	-87.32	36.0000----	-96.34	52.0000----	-103.46	68.0000----	-109.70
4.8000----	-66.71	20.8000----	-87.86	36.8000----	-96.73	52.8000----	-103.78	68.8000----	-110.00
5.6000----	-68.52	21.6000----	-88.38	37.6000----	-97.11	53.6000----	-104.11	69.6000----	-110.30
6.4000----	-70.15	22.4000----	-88.89	38.4000----	-97.49	54.4000----	-104.44	70.4000----	-110.59
7.2000----	-71.63	23.2000----	-89.39	39.2000----	-97.87	55.2000----	-104.76	71.2000----	-110.89
8.0000----	-72.99	24.0000----	-89.88	40.0000----	-98.24	56.0000----	-105.08	72.0000----	-111.18
8.8000----	-74.27	24.8000----	-90.36	40.8000----	-98.61	56.8000----	-105.40	72.8000----	-111.47
9.6000----	-75.47	25.6000----	-90.84	41.6000----	-98.97	57.6000----	-105.72	73.6000----	-111.76
10.4000----	-76.61	26.4000----	-91.30	42.4000----	-99.33	58.4000----	-106.03	74.4000----	-112.05
11.2000----	-77.69	27.2000----	-91.75	43.2000----	-99.69	59.2000----	-106.34	75.2000----	-112.34
12.0000----	-78.73	28.0000----	-92.20	44.0000----	-100.05	60.0000----	-106.66	76.0000----	-112.63
12.8000----	-79.73	28.8000----	-92.64	44.8000----	-100.40	60.8000----	-106.97	76.8000----	-112.91
13.6000----	-80.69	29.6000----	-93.08	45.6000----	-100.75	61.6000----	-107.28	77.6000----	-113.20
14.4000----	-81.62	30.4000----	-93.50	46.4000----	-101.09	62.4000----	-107.59	78.4000----	-113.49
15.2000----	-82.52	31.2000----	-93.93	47.2000----	-101.44	63.2000----	-107.89	79.2000----	-113.77
16.0000----	-83.40	32.0000----	-94.34	48.0000----	-101.78	64.0000----	-108.20	80.0000----	-114.05

***** FOR A RECEIVER INPUT LEVEL OF -90.00 DBM, DISTANCE BETWEEN ANTENNAS CAN BE AT LEAST 24.00 KM *****

--- PROGRAM PARAMETERS ---

POLARIZATION (POL)	VERTICAL	
FREQUENCY OF SIGNAL (F)	100.00	MEG-HERTZ
SURFACE CONDUCTIVITY (S)	0.01500	MHO/METER
SURFACE REFRACTIVITY (NS)	321.00	N-UNITS
SUM OF ELEVATION ANGLES (TE)	0.08069	RADIANS
DISTANCE BETWEEN ANTENNAS (DIST)	80.00	K-METERS
ATTENUATION BELOW FREE SPACE (AE)	43.57	DB
INTERDECILE RANGE OF TERRAIN HEIGHT (DH)	580.00	METERS
SUM OF SMOOTH-EARTH HORIZON DISTANCES (DLS)	19.44	K-METERS
DIFFRACTION ATTENUATION AT DISTANCE DLS (ALS)	54.71	DB
PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT (E)	20.00	
ESTIMATED SCATTER ATTENUATION BELOW FREE SPACE (AES)	95.45	DB
STRUCTURAL RECEIVER ANTENNA HEIGHT ABOVE GROUND (H2G)	3.00	METERS
STRUCTURAL TRANSMITTER ANTENNA HEIGHT ABOVE GROUND (H1G)	4.00	METERS
ESTIMATED DIFFRACTION ATTENUATION BELOW FREE SPACE (AED)	49.95	DB
COEFFICIENT THAT DEFINES SLOPE OF A SMOOTH CURVE OF ACR (K1)	0.51568	DB/KM
COEFFICIENT THAT DEFINES SLOPE OF A SMOOTH CURVE OF ACR (K2)	0.86623	DB/KM
SLOPE OF THE CURVE OF SCATTER ATTENUATION AS VERSUS DISTANCE (MS)	0.04735	DB/KM
DISTANCE WHERE DIFFRACTION AND SCATTER ATTENUATIONS ARE EQUAL (DX)	230.35	K-METERS
ATTENUATION WHERE DIFFRACTION AND SCATTER ATTENUATION ARE EQUAL (ADX)	106.35	DB
SLOPE OF THE CURVE OF DIFFRACTION ATTENUATION AS VERSUS DISTANCE (MD)	0.24484	DB/KM

--- SIGNAL STRENGTH DATA INPUT ---

TRANSMITTER POWER OUT	100.00	WATTS
TRANSMITTER TRANSMISSION LINE LOSS	2.00	DB
TRANSMITTER ANTENNA GAIN	10.00	DB
RECEIVER SENSITIVITY	-90.00	DBM
RECEIVER TRANSMISSION LINE LOSS	2.00	DB
RECEIVER ANTENNA GAIN	10.00	DB

```
C**********************************************************************JMC     0
C**********************************************************************JMC     1
C                                                                      JMC     2
C                                                                      JMC     3
C       THIS PROGRAM IS AN UPDATE OF THE ESSA RESEARCH LABORATORIES     JMC     4
C                                                                      JMC     5
C       TECHNICAL REPORT (ERL 79-ITS 67) PROGRAM TITLED "PREDICTION OF JMC     6
C                                                                      JMC     7
C       TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN".  JMC     8
C                                                                      JMC     9
C       THE FOLLOWING PROGRAM HAS CERTAIN ADVANTAGES OVER THE ABOVE    JMC    10
C                                                                      JMC    11
C       1968 COMPUTER METHOD. THE ADVANTAGES ARE:                      JMC    12
C                                                                      JMC    13
C                1. MORE ACCURACY DUE TO DOUBLE PRECISION              JMC    14
C                                                                      JMC    15
C                2. THE PROGRAM IS WRITTEN IN FORTRAN IV LANGUAGE      JMC    16
C                                                                      JMC    17
C                3. OUTPUT DATA IS PLOTTED BY A BUILT IN ROUTINE       JMC    18
C                                                                      JMC    19
C                5. OUTPUT DATA IS FULLY DESCRIBED AND EASIER TO READ  JMC    20
C                                                                      JMC    21
C                6. PROGRAM HAS PROVISION FOR SIGNAL STRENGTH DATA     JMC    22
C                                                                      JMC    23
C                7. PROGRAM LOOPS BACK TO BEGINNING TO HANDLE          JMC    24
C                                                                      JMC    25
C                   MULTIPLE PROBLEMS                                  JMC    26
C                                                                      JMC    27
C       PROGRAMMER:  LT JAMES M. CALLAGHAN USN                         JMC    28
C                                                                      JMC    29
C       DATE:        JUNE 1973                                         JMC    30
C                                                                      JMC    31
C**********************************************************************JMC    32
C**********************************************************************JMC    33
C**********************************************************************JMC    34
C                                                                      JMC    35
C                                                                      JMC    36
C                                                                      JMC    37
      IMPLICIT REAL*8(A-H,O-Z)                                         JMC    38
      COMMON /MM/F,D,NS,A,DH,DHS,S,E,POL,KM                            JMC    39
      COMMON /MP/ H1E,H2E,H1G,H2G,DLS1,DLS2,DL1,DL2,DL,DLS,TE1,TE2,TE,KLJMC    40
      COMMON /MLOS/ AG,AD,AS,ACR,AED,MD,AH50,AH5,D5,MS,AES,DX,H5       JMC    41
      COMMON /ML/ D0,D1,D01,D02,A0,A1,K1,K2,AL,ALS,A0G                 JMC    42
      DIMENSION SD(100),SA(100),DB(100)                                JMC    43
      REAL*8 NS,MD,MD0,MS,MSS,MDS,K1,K2,K3,K4,LBF                      JMC    44
C                                                                      JMC    45
C*****ALL INTEGER VALUE INPUTS FOR DATA MUST BE RIGHT JUSTIFIED*******JMC    46
C                                                                      JMC    47
```

```
C     FIRST DATA CARD                                                          JMC    48
C                                                                              JMC    49
C         COLUMN: 01-10 "TYPE OF TERRAIN" -INTEGER (RIGHT JUSTIFIED)           JMC    50
C           CODE:  1 ---"COLORADO PLAINS"          (OMIT THIRD DATA CARD)      JMC    51
C                  2 ---"COLORADO MOUNTAINS"       (OMIT THIRD DATA CARD)      JMC    52
C                  3 ---"OHIO"                     (OMIT THIRD DATA CARD)      JMC    53
C                  4 ---"USER TERRAIN DATA" WITHOUT DATA SUPPRESSION           JMC    54
C                  5 ---"USER TERRAIN DATA" NO "OUTPUT PARAMETERS"             JMC    55
C                       PRINTED                                                JMC    56
C         COLUMN: 11-20 "DB LOSS"                                              JMC    57
C           CODE: 0  NO DB DATA DESIRED (OMIT SECOND DATA CARD)                JMC    58
C           CODE: 1  DB DATA DESIRED (MUST INCLUDE SECOND DATA CARD)           JMC    59
C         COLUMN: 21-30 "DISTANCE BETWEEN ANTENNAS" (1-2,000) K-METERS         JMC    60
C                       -REAL                                                  JMC    61
C                                                                              JMC    62
C                                                                              JMC    63
C                                                                              JMC    64
   19 READ (5,20,END=9999) ITERR,IDB,DIST                                      JMC    65
   20 FORMAT (2I10,F10.5)                                                      JMC    66
C                                                                              JMC    67
C                                                                              JMC    68
C                                                                              JMC    69
C     SECOND DATA CARD (USED FOR SIGNAL STRENGTH DB DATA OUT)                  JMC    70
C                                                                              JMC    71
C         COLUMN: 01-10 "TX POWER OUT" (WATTS) -REAL(+) POSITIVE NUMBER        JMC    72
C         COLUMN: 11-20 "TX ANTENNA GAIN" (DB) -REAL(+)                        JMC    73
C         COLUMN: 21-30 "RX ANTENNA GAIN" (DB) -REAL(+)                        JMC    74
C         COLUMN: 31-40 "TRANSMISSION LINE LOSS" (DB) -REAL(+)                 JMC    75
C         COLUMN: 41-50 "RECEIVER LINE LOSS" (DB) -REAL(+)                     JMC    76
C         COLUMN: 51-60 "RECEIVER INPUT LEVEL" (DBM) -REAL(+)                  JMC    77
C                                                                              JMC    78
C                                                                              JMC    79
C                                                                              JMC    80
   25 IF (IDB.NE.1) GO TO 24                                                   JMC    81
      READ (5,23) TXPO,TXAG,RXAG,TRLL,RXLL,RXIN                                JMC    82
   23 FORMAT (6F10.2)                                                          JMC    83
      DDB=10*DLOG10(TXPO)+TXAG+RXAG-TRLL-RXLL                                  JMC    84
C                                                                              JMC    85
C                                                                              JMC    86
C                                                                              JMC    87
C     THIRD DATA CARD                                                          JMC    88
C                                                                              JMC    89
C         COLUMN: 01-10 "SURFACE REFRACTIVITY" (250-400 N-UNITS)-INTEGERJMC    90
C                       (RIGHT JUSTIFIED)                                      JMC    91
C         COLUMN: 11-20 "SURFACE CONDUCTIVITY" MHO/METER  -REAL                JMC    92
C         COLUMN: 21-30 "PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT"         JMC    93
C                       -REAL                                                  JMC    94
C         COLUMN: 31-40 "INTERDECILE RANGE" DELTA-H -REAL                      JMC    95
```

```
C                                                                       JMC   96
C                                                                       JMC   97
C                                                                       JMC   98
   24 IF (ITERR.LT.4) GO TO 26                                          JMC   99
      READ (5,21) NSS,SS,EE,DHH                                         JMC  100
   21 FORMAT (I10,3F10.5)                                               JMC  101
C                                                                       JMC  102
CCCCC                                                                   JMC  103
CCCCC                                                                   JMC  104
CCCCC    FOURTH DATA CARD                                               JMC  105
CCCCC                                                                   JMC  106
CCCCC        COLUMN: 01-10 "ANTENNA POLARIZATION" -REAL                 JMC  107
CCCCC          CODE: +1.00 VERTICAL POLARIZATION                        JMC  108
CCCCC            ''  -1.00 HORIZONAL POLARIZATION                      JMC  109
CCCCC        COLUMN: 11-20 "FREQUENCY" MEGAHERTZ (20-40,000) -REAL      JMC  110
CCCCC        COLUMN: 21-30 "STRUCTURAL ANTENNA HEIGHT OF TRANSMITTING   JMC  111
CCCCC                      ANTENNA" (0.5-3000.0) METERS -REAL           JMC  112
CCCCC        COLUMN: 31-40 "STRUCTURAL ANTENNA HEIGHT OF RECEIVER ANTENNA" JMC 113
CCCCC                      (0.5-3000.0) METERS  -REAL                   JMC  114
CCCCC                                                                   JMC  115
CCCCC                                                                   JMC  116
C                                                                       JMC  117
   26 READ (5,22) POL,F,H1G,H2G                                         JMC  118
   22 FORMAT (4F10.5)                                                   JMC  119
C                                                                       JMC  120
CCCCC                                                                   JMC  121
CCCCC    COLORADO PLAINS TERRAIN DATA                                   JMC  122
CCCCC                                                                   JMC  123
C                                                                       JMC  124
      NS=290.                                                           JMC  125
      S=.005                                                            JMC  126
      E=15.                                                             JMC  127
      DH=90.                                                            JMC  128
      DHS=90.                                                           JMC  129
      IF (ITERR.EQ.2) GO TO 3                                           JMC  130
      IF (ITERR.EQ.3) GO TO 5                                           JMC  131
      IF (ITERR.GT.3.AND.ITERR.LT.6) GO TO 7                            JMC  132
C                                                                       JMC  133
CCCCC                                                                   JMC  134
CCCCC    WRITE OUT COLORADO PLAINS TERRAIN HEADING                      JMC  135
CCCCC                                                                   JMC  136
C                                                                       JMC  137
      WRITE (6,2)                                                       JMC  138
    2 FORMAT     ('1',////////,54X,'--- COLORADO PLAINS ---',/)         JMC  139
      GO TO 9                                                           JMC  140
C                                                                       JMC  141
CC                                                                      JMC  142
C     COLORADO MOUTAIN TERRAIN DATA                                     JMC  143
```

```
C                                                                       JMC  144
C                                                                       JMC  145
    3 DH=650.                                                           JMC  146
      DHS=650.                                                          JMC  147
C                                                                       JMC  148
C     WRITE OUT COLORADO MOUNTAINS TERRAIN HEADING                      JMC  149
C                                                                       JMC  150
      WRITE (6,4)                                                       JMC  151
    4 FORMAT     ('1',////////,53X,'--- COLORADO MOUNTAINS ---',/)      JMC  152
      GO TO 9                                                           JMC  153
C                                                                       JMC  154
C     OHIO TERRAIN DATA                                                 JMC  155
C                                                                       JMC  156
    5 NS=312.                                                           JMC  157
C                                                                       JMC  158
C     WRITE OUT OHIO TERRAIN HEADING                                    JMC  159
C                                                                       JMC  160
      WRITE (6,6)                                                       JMC  161
    6 FORMAT     ('1',////////,60X,'--- OHIO ---',/)                    JMC  162
      GO TO 9                                                           JMC  163
C                                                                       JMC  164
C     USER TERRAIN DATA                                                 JMC  165
C                                                                       JMC  166
    7 NS=NSS                                                            JMC  167
      S=SS                                                              JMC  168
      E=EE                                                              JMC  169
      DH=DHH                                                            JMC  170
      DHS=DHH                                                           JMC  171
C                                                                       JMC  172
C     WRITE OUT USER TERRAIN HEADING                                    JMC  173
C                                                                       JMC  174
      WRITE (6,8)                                                       JMC  175
    8 FORMAT     ('1',////////,53X,'--- USER TERRAIN DATA ---',/)       JMC  176
C                                                                       JMC  177
C     WRITE OUT SIGNAL FREQUENCY                                        JMC  178
C                                                                       JMC  179
```

```
    9   WRITE (6,27) F                                                          JMC  192
   27   FORMAT (///,2X,                                                         JMC  193
     *'FREQUENCY OF SIGNAL -F- (MEG-HERTZ)',02X,F10.5,/////////////)           JMC  194
C                                                                              JMC  195
CCCC                                                                           JMC  196
CCCC    CALCULATION OF H1E AND H2E                                             JMC  197
CCCC                                                                           JMC  198
C                                                                              JMC  199
        H1E=H1G                                                                JMC  200
        IF (H1G.LE.2.0) GO TO 12                                               JMC  201
        IF (H1G.GE.2.0.OR.H1G.LE.5.0) GO TO 10                                 JMC  202
        Z1=5.0                                                                 JMC  203
        GO TO 11                                                               JMC  204
   10   Z1=1.0+DSIN(3.1415927*H1G/10.0)                                        JMC  205
   11   H1E=H1G+Z1*DEXP(-2.0*H1G/DH)                                           JMC  206
   12   H2E=H2G                                                                JMC  207
        IF (H2G.LE.2.0) GO TO 15                                               JMC  208
        IF (H2G.GE.2.0.OR.H2G.LE.5.0) GO TO 13                                 JMC  209
        Z2=5.0                                                                 JMC  210
        GO TO 14                                                               JMC  211
   13   Z2=1.0+DSIN(3.1415927*H2G/10.0)                                        JMC  212
   14   H2E=H2G+Z2*DEXP(-2.0*H2G/DH)                                           JMC  213
   15   CONTINUE                                                               JMC  214
        A=6370./(1.-.04665*DEXP(.005577*NS))                                   JMC  215
        DLS1=DSQRT(.002*A*H1E)                                                 JMC  216
        DLS2=DSQRT(.002*A*H2E)                                                 JMC  217
        DLS=DLS1+DLS2                                                          JMC  218
        DL1=DLS1*DEXP(-.07*DSQRT(DH/DMAX1(5.0D0,H1E)))                         JMC  219
        DL2=DLS2*DEXP(-.07*DSQRT(DH/DMAX1(5.0D0,H2E)))                         JMC  220
        DL=DL1+DL2                                                             JMC  221
        TE1=(.00065/DLS1)*((DLS1/DL1-1.)*DH-3.077*H1E)                         JMC  222
        TE2=(.00065/DLS2)*((DLS2/DL2-1.)*DH-3.077*H2E)                         JMC  223
        TE=DMAX1((TE1+TE2),(-DL/A))                                            JMC  224
C                                                                              JMC  225
CCCCC                                                                          JMC  226
CCCCC   START OF "DELTA-DISTANCE" LOOP                                         JMC  227
CCCCC                                                                          JMC  228
C                                                                              JMC  229
        DMAX=0.0                                                               JMC  230
        DO 300 IDIS=1,100                                                      JMC  231
        D=DIST*IDIS/100.0                                                      JMC  232
        IF (IDIS.EQ.100) D=DIST                                                JMC  233
        IF (D .GT. DLS) GO TO 40                                               JMC  234
C                                                                              JMC  235
CCCCC                                                                          JMC  236
CCCCC   CALL SUBROUTINE "LOS"                                                  JMC  237
CCCCC                                                                          JMC  238
C                                                                              JMC  239
```

```
      CALL LOS                                                          JMC  240
C                                                                       JMC  241
CCCCC                                                                   JMC  242
      STORE ATTENUATION (ACR) AND DISTANCE (D) DATA                     JMC  243
CCCCC                                                                   JMC  244
                                                                        JMC  245
      SD(IDIS)=D                                                        JMC  246
      ACT=ACR+32.45+20*DLOG10(F)+20*DLOG10(D)                           JMC  247
      SA(IDIS)=ACT                                                      JMC  248
      GO TO 300                                                         JMC  249
C                                                                       JMC  250
CCCCC                                                                   JMC  251
      CALL SUBROUTINE "DIFF"                                            JMC  252
CCCCC                                                                   JMC  253
                                                                        JMC  254
   40 CALL DIFF                                                         JMC  255
      SD(IDIS)=D                                                        JMC  256
      ACT=ACR+32.45+20*DLOG10(F)+20*DLOG10(D)                           JMC  257
      SA(IDIS)=ACT                                                      JMC  258
      AE=AOG-K1*DO-K2*DLOG10(DO)                                        JMC  259
      ADX=AED+MD*DX                                                     JMC  260
      IF(-RXIN.LT.DDB-ACT+30.0) DMAX=D                                  JMC  261
C                                                                       JMC  262
                                                                        JMC  263
CCCCCC                                                                  JMC  264
      END OF "100 POINT DISTANCE" LOOP                                  JMC  265
CCCCCC                                                                  JMC  266
                                                                        JMC  267
  300 DB(IDIS)=DDB-ACT+30.0                                             JMC  268
C                                                                       JMC  269
                                                                        JMC  270
CCCCCC                                                                  JMC  271
      WRITE "DISTANCE, TRANS-LOSS" HEADING AND DATA.                    JMC  272
CCCCCC                                                                  JMC  273
                                                                        JMC  274
      WRITE (6,301)                                                     JMC  275
  301 FORMAT(1X,5(3X,'DISTANCE',2X,'TRANS-LOSS ',2X))                   JMC  276
      WRITE(6,3011)                                                     JMC  277
 3011 FORMAT(5(6X,'(KM)',7X,'(DB)',5X),///)                             JMC  278
      DO 303 K=1,20                                                     JMC  279
      WRITE(6,302) (SD(K+20*(N-1)),SA(K+20*(N-1)),N=1,5)                JMC  280
  302 FORMAT(2X,5(F8.4,'------',F6.2,6X),/)                             JMC  281
  303 CONTINUE                                                          JMC  282
C                                                                       JMC  283
CCCCC                                                                   JMC  284
      SCALE GRAPH FOR ATTENUATION.                                      JMC  285
CCCCC                                                                   JMC  286
                                                                        JMC  287
      SCAL=0.0
```

```
   70  SCAL=SCAL+1.0                                                          JMC  288
       SCA=SCAL*6.0                                                           JMC  289
       IF(SA(100).LE.SCA) GO TO 71                                            JMC  290
       GO TO 70                                                               JMC  291
   71  RA1=SD(100)                                                            JMC  292
       RA2=0.0                                                                JMC  293
       RA3=SCA                                                                JMC  294
       DO 80 II=1,6                                                           JMC  295
       SCAA=(SCA/6)*II                                                        JMC  296
       IF (SCAA.GE.SA(1)) GO TO 81                                            JMC  297
    80 CONTINUE                                                               JMC  298
   81  RA4=SCAA-SCA/6                                                         JMC  299
C                                                                             JMC  300
CCC                                                                           JMC  301
CCCC   PLOT TRANS-LOSS (DB) VS DISTANCE (KM).                                 JMC  302
CCC                                                                           JMC  303
C                                                                             JMC  304
       WRITE(6,72)                                                            JMC  305
   72  FORMAT('1',48X,'PLOT OF TRANS.-LOSS VERSUS DISTANCE',///)              JMC  306
       IF(IDB.NE.1) GO TO 723                                                 JMC  307
       DDC=DDB+30.0                                                           JMC  308
       WRITE(6,722) DDC                                                       JMC  309
  722  FORMAT(' ** NOTE **  TO FIND SIGNAL STRENGTH FROM GRAPH, SUBTRACT      JMC  310
      *TRANS.-LOSS FROM',F7.2,////)                                           JMC  311
  723  CALL UTPLOT (SD,SA,100,RA1,RA2,RA3,RA4,2,0)                            JMC  312
       WRITE(6,85)                                                            JMC  313
   85  FORMAT(//,1X,'TRANS-LOSS  (DB)',30X,'DISTANCE (K-METERS)')             JMC  314
       IF(IDB.NE.1) GO TO 308                                                 JMC  315
C                                                                             JMC  316
CCC                                                                           JMC  317
CCCC   WRITE "DISTANCE AND SIGNAL STRENGTH" HEADING AND DATA.                 JMC  318
CCC                                                                           JMC  319
C                                                                             JMC  320
       WRITE (6,304)                                                          JMC  321
  304  FORMAT('1',33X,'--- SIGNAL STRENGTH VERSUS DISTANCE FOR GIVEN SYST     JMC  322
      *EM PARAMETERS ---',/////////,1X,5(3X,'DISTANCE',2X,'SIG-STRENGTH'     JMC  323
      *,1X))                                                                  JMC  324
       WRITE(6,3041)                                                          JMC  325
 3041  FORMAT(1X,5(5X,'(KM)',8X,'(DBM)',4X),///)                              JMC  326
       DO 306 K=1,20                                                          JMC  327
       WRITE(6,305) (SD(K+20*(N-1)),DB(K+20*(N-1)),N=1,5)                     JMC  328
  305  FORMAT(2X,5(F8.4,'----',F8.2,6X),/)                                    JMC  329
  306  CONTINUE                                                               JMC  330
       RXGG=-RXIN                                                             JMC  331
       WRITE (6,307) RXGG,DMAX                                                JMC  332
  307  FORMAT(/////,9X,'****' FOR A RECEIVER INPUT LEVEL OF ',F07.2,          JMC  333
      *' DBM, DISTANCE BETWEEN ANTENNAS CAN BE AT LEAST',F07.2,               JMC  334
      *' KM ****')                                                            JMC  335
```

```
C                                                                       JMC  336
C                                                                       JMC  337
C     WRITE OUTPUT PARAMETERS                                           JMC  338
C                                                                       JMC  339
C                                                                       JMC  340
  308 IF(ITERR.EQ.5) GO TO 69                                           JMC  341
      WRITE(6,74)                                                       JMC  342
   74 FORMAT('1',52X,'--- PROGRAM PARAMETERS ---',///)                  JMC  343
      IF(POL.GT.0.0) GO TO 61                                           JMC  344
      WRITE(6,60)                                                       JMC  345
   60 FORMAT(    //,15X,'POLARIZATION (POL)  ---------------------------JMC  346
     *---------------------------- HORIZONTAL',/)                       JMC  347
      GO TO 63                                                          JMC  348
   61 WRITE(6,62)                                                       JMC  349
   62 FORMAT(    //,15X,'POLARIZATION (POL)  ---------------------------JMC  350
     *---------------------------- VERTICAL',/)                         JMC  351
   63 WRITE(6,64) F,S,NS,TE,DIST,AE,DH,DLS,ALS                          JMC  352
   64 FORMAT(15X,   'FREQUENCY OF SIGNAL (F)  ---------------------------JMC  353
     *----------------------',F7.2  ,'  MEG-HERTZ ',//,                  JMC  354
     *15X,           'SURFACE CONDUCTIVITY (S)  -------------------------JMC  355
     *----------------------',F7.5  ,'  MHO/METER ',//,                  JMC  356
     *15X,           'SURFACE REFRACTIVITY (NS)  ------------------------JMC  357
     *----------------------',F7.2  ,'  N-UNITS   ',//,                  JMC  358
     *15X,           'SUM OF ELEVATION ANGLES (TE)  ---------------------JMC  359
     *----------------------',F7.5  ,'  RADIANS   ',//,                  JMC  360
     *15X,           'DISTANCE BETWEEN ANTENNAS (DIST)  -----------------JMC  361
     *----------------------',F7.2  ,'  K-METERS  ',//,                  JMC  362
     *15X,           'ATTENUATION BELOW FREE SPACE (AE)  ----------------JMC  363
     *----------------------',F7.2  ,'  DB        ',//,                  JMC  364
     *15X,           'INTERDECILE RANGE OF TERRAIN HEIGHT (DH)  ---------JMC  365
     *----------------------',F7.2  ,'  METERS    ',//,                  JMC  366
     *15X,           'SUM OF SMOOTH-EARTH HORIZON DISTANCES (DLS)  ------JMC  367
     *----------------------',F7.2  ,'  K-METERS  ',//,                  JMC  368
     *15X,           'DIFFRACTION ATTENUATION AT DISTANCE DLS (ALS)  ----JMC  369
     *----------------------',F7.2  ,'  DB        ',/)                   JMC  370
      WRITE(6,65) E,AES,H2G,H1G,AED,K1,K2,MS                            JMC  371
   65 FORMAT(15X,   'PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT (E)  -JMC  372
     *----------------------',F7.2                ,//,                  JMC  373
     *15X,           'ESTIMATED SCATTER ATTENUATION BELOW FREE SPACE (AESJMC  374
     *)  ------------------',F7.2  ,'  DB        ',//,                  JMC  375
     *15X,           'STRUCTURAL RECEIVER ANTENNA HEIGHT ABOVE GROUND (H2JMC  376
     *G)------------------',F7.2  ,'  METERS    ',//,                  JMC  377
     *15X,           'STRUCTURAL TRANSMITTER ANTENNA HEIGHT ABOVE GROUND JMC  378
     *(H1G)  -------------',F7.2  ,'  METERS    ',//,                  JMC  379
     *15X,           'ESTIMATED DIFFRACTION ATTENUATION BELOW FREE SPACE JMC  380
     *(AED)  -------------',F7.2  ,'  DB        ',//,                  JMC  381
     *15X,           'COEFFICIENT THAT DEFINES SLOPE OF A SMOOTH CURVE OFJMC  382
     * ACR (K1)  ---------',F7.5  ,'  DB/KM     ',//,                  JMC  383
```

```
     *15X,          'COEFFICIENT THAT DEFINES SLOPE OF A SMOOTH CURVE OFJMC  384
     * ACR (K2)  -----------',F7.5  ,'  DB/KM      ',//,                  JMC  385
     *15X,          'SLOPE OF THE CURVE OF SCATTER ATTENUATION AS VERSUSJMC  386
     * DISTANCE (MS)  ------',F7.5  ,'  DB/KM      ',/)                   JMC  387
       WRITE(6,66) DX,ADX,MD                                              JMC  388
  66   FORMAT(15X,    'DISTANCE WHERE DIFFRACTION AND SCATTER ATTENUATIONSJMC  389
     * ARE EQUAL (DX)  -----',F7.2  ,'  K-METERS   ',//,                  JMC  390
     *15X,          'ATTENUATION WHERE DIFFRACTION AND SCATTER ATTENUATIJMC  391
     *ON ARE EQUAL (ADX)  --',F7.2  ,'  DB         ',//,                  JMC  392
     *15X,          'SLOPE OF THE CURVE OF DIFFRACTION ATTENUATION AS VEJMC  393
     *RSUS DISTANCE (MD)  --',F7.5  ,'  DB/KM      ',//)                  JMC  394
       IF(IDB.NE.1) GO TO 69                                              JMC  395
  67   WRITE(6,68) TXPO,TRLL,TXAG,RXGG,RXLL,RXAG                          JMC  396
  68   FORMAT(////////,44X,'--- SIGNAL STRENGTH DATA INPUT ---',//////,   JMC  397
     *15X,          'TRANSMITTER POWER OUT  ----------------------------JMC  398
     *----------------------',F7.2  ,'  WATTS     ',//,                  JMC  399
     *15X,          'TRANSMITTER TRANSMISSION LINE LOSS  ---------------JMC  400
     *----------------------',F7.2  ,'  DB        ',//,                  JMC  401
     *15X,          'TRANSMITTER ANTENNA GAIN  -------------------------JMC  402
     *----------------------',F7.2  ,'  DB        ',//,                  JMC  403
     *15X,          'RECEIVER SENSITIVITY  -----------------------------JMC  404
     *----------------------',F7.2  ,'  DBM       ',//,                  JMC  405
     *15X,          'RECEIVER TRANSMISSION LINE LOSS  ------------------JMC  406
     *----------------------',F7.2  ,'  DB        ',//,                  JMC  407
     *15X,          'RECEIVER ANTENNA GAIN  ----------------------------JMC  408
     *----------------------',F7.2  ,'  DB        ',/)                   JMC  409
  69   CONTINUE                                                           JMC  410
CCCCC                                                                    JMC  411
                                                                         JMC  412
       START PROGRAM AGAIN                                               JMC  413
                                                                         JMC  414
CCCCC                                                                    JMC  415
       GO TO 19                                                          JMC  416
 9999  CONTINUE                                                          JMC  417
       STOP                                                              JMC  418
       END                                                               JMC  419

       SUBROUTINE DIFF                                                   JMC  420
C                                                                        JMC  421
CCC    SUBROUTINE TO COMPUTE DIFFRACTION ATTENUATION                     JMC  422
C                                                                        JMC  423
       IMPLICIT REAL*8(A-H,O-Z)                                          JMC  424
       COMMON /NR/W,SW3,SW4,SA3,SA4,SAFO,JZ                              JMC  425
       COMMON /MAR14/D3,D4,T5                                            JMC  426
       COMMON /MM/F,D,NS,A,DH,DHS,S,E,PCL,KM                             JMC  427
       COMMON /MP/ H1E,H2E,H1G,H2G,DLS1,DLS2,DL1,DL2,DL,DLS,TE1,TE2,TE,KLJMC  428
       COMMON /MLDS/ AG,AD,AS,ACR,AED,MD,AH50,AH5,D5,MS,AES,DX,H5        JMC  429
```

```
      REAL*8 NS,MD,MDO,MS,MSS,MDS,K1,K2,K3,K4                           JMC  430
      X=18000.*S/F                                                      JMC  431
      RDL=DL                                                            JMC  432
      KK=0                                                              JMC  433
   10 KK=KK+1                                                           JMC  434
      D3=DL+.5*(A*A/F)**.3333333333                                     JMC  435
      IF (D3 .LT. DLS)  D3=DLS                                          JMC  436
      D4=D3+(A*A/F)**.3333333333                                        JMC  437
      T3=TE+D3/A                                                        JMC  438
      T4=TE+D4/A                                                        JMC  439
C                                                                       JMC  440
C     CALCULATION OF KNIFE EDGE DIFFRACTION                             JMC  441
C                                                                       JMC  442
      V13=1.2915*T3*DSQRT(F*DL1*(D3-DL)/(D3-DL2))                       JMC  443
      V23=1.2915*T3*DSQRT(F*DL2*(D3-DL)/(D3-DL1))                       JMC  444
      V14=1.2915*T4*DSQRT(F*DL1*(D4-DL)/(D4-DL2))                       JMC  445
      V24=1.2915*T4*DSQRT(F*DL2*(D4-DL)/(D4-DL1))                       JMC  446
      AV13=FNA(V13)                                                     JMC  447
      IF(V13 .GT. 2.4) AV13=FNB(V13)                                    JMC  448
      AV23=FNA(V23)                                                     JMC  449
      IF(V23 .GT. 2.4) AV23=FNB(V23)                                    JMC  450
      AV14=FNA(V14)                                                     JMC  451
      IF (V14 .GT. 2.4) AV14=FNB(V14)                                   JMC  452
      AV24=FNA(V24)                                                     JMC  453
      IF(V24 .GT. 2.4) AV24=FNB(V24)                                    JMC  454
      AK3=AV13+AV23                                                     JMC  455
      AK4=AV14+AV24                                                     JMC  456
C                                                                       JMC  457
C     CALCULATION OF ROUNDED EARTH DIFFRACTION                          JMC  458
C                                                                       JMC  459
      A1=DL1*DL1/(.002*H1E)                                             JMC  460
      A2=DL2*DL2/(.002*H2E)                                             JMC  461
      A3=(D3-DL)/T3                                                     JMC  462
      A4=(D4-DL)/T4                                                     JMC  463
      K1=FND(A1,F,E,X)                                                  JMC  464
      K2=FND(A2,F,E,X)                                                  JMC  465
      K3=FND(A3,F,E,X)                                                  JMC  466
      K4=FND(A4,F,E,X)                                                  JMC  467
      IF (POL .EQ. -1.) GO TO 15                                        JMC  468
      K1=FNE(K1,E,X)                                                    JMC  469
      K2=FNE(K2,E,X)                                                    JMC  470
      K3=FNE(K3,E,X)                                                    JMC  471
      K4=FNE(K4,E,X)                                                    JMC  472
   15 B1=FNC(K1,F)                                                      JMC  473
      B2=FNC(K2,F)                                                      JMC  474
      B3=FNC(K3,F)                                                      JMC  475
      B4=FNC(K4,F)                                                      JMC  476
      X1=B1*DL1/A1**.6666666666                                         JMC  477
```

```
      X2=B2*DL2/A2**.6666666666                                                  JMC  478
      X3=B3*(D3-DL)/A3**.6666666666+X1+X2                                        JMC  479
      X4=B4*(D4-DL)/A4**.6666666666+X1+X2                                        JMC  480
      XL1=450./DABS(DLOG10(K1)**3)                                               JMC  481
      XL2=450./DABS(DLOG10(K2)**3)                                               JMC  482
      IF(X1.GT.0..AND.X1.LE. 200.    .AND.K1 .GE. 0..AND. K1.LE. .00001)         JMC  483
     C GO TO 16                                                                  JMC  484
      GO TO 17                                                                   JMC  485
   16 T=40.*DLOG10(X1)-117.                                                      JMC  486
      T1=-117.                                                                   JMC  487
      T2=DMIN1((DABS(T)),(DABS(T1)))                                             JMC  488
      FX1=T                                                                      JMC  489
      IF (T2 .EQ. DABS(T1)) FX1=T1                                               JMC  490
   17 IF(X2.GT.0..AND. X2.LE.200. .AND. K2 .GE.0..AND. K2.LE. .00001)            JMC  491
     C GO TO 18                                                                  JMC  492
      GO TO 19                                                                   JMC  493
   18 T=40.*DLOG10(X2)-117.                                                      JMC  494
      T1=-117.                                                                   JMC  495
      T2=DMIN1((DABS(T)),(DABS(T1)))                                             JMC  496
      FX2=T                                                                      JMC  497
      IF (T2 .EQ. DABS(T1)) FX2=T1                                               JMC  498
   19 IF(X1 .GT.0. .AND.X1 .LE.200. .AND.K1 .GT. .00001 .AND. K1 .LT. 1.        JMC  499
     C) GO TO 21                                                                 JMC  500
      GO TO 22                                                                   JMC  501
   21 FX1=40.*DLOG10(X1)-117.                                                    JMC  502
      IF (X1 .LE. XL1)  FX1=20.*DLOG10(K1)+2.5*1. E-5*X1/K1-15.                  JMC  503
   22 IF(X2 .GT.0. .AND.X2 .LE.200. .AND.K2 .GT. .00001 .AND.K2 .LT. 1.         JMC  504
     C) GO TO 23                                                                 JMC  505
      GO TO 24                                                                   JMC  506
   23 FX2=40.*DLOG10(X2)-117.                                                    JMC  507
      IF (X2 .LE. XL2)  FX2=20.*DLOG10(K2)+2.5*1. E-5*X2*X2/K2-15.               JMC  508
   24 W1=.0134*X1*DEXP(-.005*X1)                                                 JMC  509
      W2=.0134*X2*DEXP(-.005*X2)                                                 JMC  510
      IF(X1.GT.200. .AND. X1.LE.2000.)                                           JMC  511
     C FX1=W1*(40.*DLOG10(X1)-117.)+(1.-W1)*(.05751*X1-10.*DLOG10(X1))           JMC  512
      IF(X2 .GT. 200. .AND. X2 .LE. 2000.)                                       JMC  513
     CFX2=W2*(40.*DLOG10(X2)-117.)+(1.-W2)*(.05751*X2-10.*DLOG10(X2))           JMC  514
      IF(X1.GT. 2000.) FX1=.05751*X1-10.*DLOG10(X1)                              JMC  515
      IF(X2.GT. 2000.) FX2=.05751*X2-10.*DLOG10(X2)                              JMC  516
      GX3=.05751*X3-10.*DLOG10(X3)                                               JMC  517
      GX4=.05751*X4-10.*DLOG10(X4)                                               JMC  518
      AR3=GX3-FX1-FX2-20.                                                        JMC  519
      AR4=GX4-FX1-FX2-20.                                                        JMC  520
C                                                                                JMC  521
C     COMBINATION OF ROUNDED EARTH AND KNIFE EDGE DIFFRACTION                    JMC  522
C                                                                                JMC  523
   28 DHD3=DH*(1.-.8*DEXP(-.02*D3))                                             JMC  524
      DHD4=DH*(1.-.8*DEXP(-.02*D4))                                             JMC  525
```

```
      P13=DSQRT((H1E*H2E)/(H1G*H2G))+(A*TE+DL)/D3                        JMC  526
      P14=DSQRT((H1E*H2E)/(H1G*H2G))+(A*TE+DL)/D4                        JMC  527
      DOL3=DMIN1(1000.0D0,(DHD3*F/299.7925))                            JMC  528
      DOL4=DMIN1(1000.0D0,(DHD4*F/299.7925))                            JMC  529
   63 W3=1./(1.+.1*DSQRT(DOL3*P13))                                     JMC  530
      W4=1./(1.+.1*DSQRT(DOL4*P14))                                     JMC  531
      A3=(1.-W3)*AK3+W3*AR3                                             JMC  532
      A4=(1.-W4)*AK4+W4*AR4                                             JMC  533
      MD=(A4-A3)/(D4-D3)                                                JMC  534
      AED=A4-MD*D4                                                      JMC  535
      DHDLS=DH*(1.-.8*DEXP(-.02*DLS))                                   JMC  536
      SHDLS=.78*DHDLS*DEXP(-.5*(DHDLS**.25))                            JMC  537
      AFO=5.*DLOG10(1.+H1G*H2G*F*SHDLS*.00001)                          JMC  538
      AFO=DMIN1(AFO,15.0D0)                                             JMC  539
   91 AED=AED+AFO                                                       JMC  540
      IF (KM .EQ. 2) GO TO 40                                           JMC  541
      IF (KK .EQ. 2) GO TO 20                                           JMC  542
      SAFO=AFO                                                          JMC  543
      SW3=W3                                                            JMC  544
      SW4=W4                                                            JMC  545
      SA3=A3                                                            JMC  546
      SA4=A4                                                            JMC  547
   29 AD=AED+MD*D                                                       JMC  548
   32 TD=(TE+D/A)*D                                                     JMC  549
      SDL1=DL1                                                          JMC  550
      SDL2=DL2                                                          JMC  551
      SDL=DL                                                            JMC  552
      STE1=TE1                                                          JMC  553
      STE2=TE2                                                          JMC  554
      STE=TE                                                            JMC  555
C                                                                       JMC  556
CCC   CALCULATION OF SCATTER ATTENUATION                                JMC  557
C                                                                       JMC  558
      CALL SCATT                                                        JMC  559
      IF (H5 .LE. 10.) AES=AH5 -MS*D5                                   JMC  560
      IF (H5 .LE. 10.) AS=AES+MS*D                                      JMC  561
      IF (H5 .LE. 10.) GO TO 30                                         JMC  562
      MDS=MD                                                            JMC  563
      AEDS=AED                                                          JMC  564
      DH=0.                                                             JMC  565
      GO TO 10                                                          JMC  566
   20 ADO=AED                                                           JMC  567
      MDO=MD                                                            JMC  568
      MD=MDS                                                            JMC  569
      AED=AEDS                                                          JMC  570
      DX1=(AH50-MS*D5-ADO)/(MDO-MS)                                     JMC  571
      DX2=(RDL+.25*(A*A/F)**.3333333333*DLOG10(F))                      JMC  572
      DXO=DX1*(3.-.2*H5)+DX2*(.2*H5-2.)                                 JMC  573
```

```
      AXO=ADO+MDO*DXO                                                    JMC  574
      ASX=AXO+(AH5-AH50)                                                 JMC  575
      AES=ASX-MS*DXO                                                     JMC  576
      AS=AES+MS*D                                                        JMC  577
   30 DX=(AES-AED)/(MD-MS)                                               JMC  578
      DXN=DL+.25*(A*A/F)**.3333333333*DLOG10(F)                          JMC  579
      IF(DXN .GT. DX) AES=AED+(MD-MS)*DXN                                JMC  580
      IF(DXN .GT. DX) AS=AES+MS*D                                        JMC  581
      IF (DXN .GT. DX) DX=DXN                                            JMC  582
      ACR=AD                                                             JMC  583
      IF (D .GT. DX) ACR=AS                                              JMC  584
      DL1=SDL1                                                           JMC  585
      DL2=SDL2                                                           JMC  586
      DL=SDL                                                             JMC  587
      TE1=STE1                                                           JMC  588
      TE2=STE2                                                           JMC  589
      TE=STE                                                             JMC  590
      DH=DHS                                                             JMC  591
   41 CONTINUE                                                           JMC  592
   40 RETURN                                                             JMC  593
      END                                                                JMC  594

      SUBROUTINE SCATT                                                   JMC  595
C                                                                        JMC  596
C     SUBROUTINE TO COMPUTE SCATTER PARAMETERS                           JMC  597
C                                                                        JMC  598
      IMPLICIT REAL*8(A-H,O-Z)                                           JMC  599
      COMMON /MM/F,D,NS,A,DH,DHS,S,E,POL,KM                              JMC  600
      COMMON /MP/H1E,H2E,H1G,H2G,DLS1,DLS2,DL1,DL2,DL,DLS,TE1,TE2,TE,KL  JMC  601
      COMMON /MAR14/D3,D4,T5                                             JMC  602
      COMMON /MLDS/ AG,AD,AS,ACR,AED,MD,AH50,AH5,D5,MS,AFS,DX,H5         JMC  603
      REAL*8 NS,MD,MDO,MS,MSS,MDS,K1,K2,K3,K4                           JMC  604
      KK=0                                                               JMC  605
   10 KK=KK+1                                                            JMC  606
      D5=DL+200.                                                         JMC  607
      D6=DL+400.                                                         JMC  608
   11 T5=TE+D5/A                                                         JMC  609
      T6=TE+D6/A                                                         JMC  610
      H5=DMIN1(((1./H1E +1./H2E)/(T5*F*DABS(.007-.058*T5))),(15.0D0))    JMC  611
      H6=DMIN1(((1./H1E +1./H2E)/(T6*F*DABS(.007-.058*T6))),(15.0D0))    JMC  612
      S5=H5+10.*DLOG10(F*T5**4)-.1*(NS-301.)*DEXP(-T5*D5/40.)            JMC  613
      S6=H6+10.*DLOG10(F*T6**4)-.1*(NS-301.)*DEXP(-T6*D6/40.)            JMC  614
      IF(T5*D5 .LT. 10.) AH5=S5+103.4+.332*T5*D5-10.*DLOG10(T5*D5)       JMC  615
      IF(T6*D6 .LT. 10.) AH6=S6+103.4+.332*T6*D6-10.*DLOG10(T6*D6)       JMC  616
      IF(T5*D5 .GT. 10. .AND.T5*D5.LE. 70.) AH5=S5+97.1+.212*T5*D5-2.5*  JMC  617
     CDLOG10(T5*D5)                                                      JMC  618
      IF(T6*D6 .GT. 10. .AND.T6*D6.LE. 70.) AH6=S6+97.1+.212*T6*D6-2.5*  JMC  619
```

```
      CDLOG10(T6*D6)                                                    JMC  620
        IF(T5*D5 .GT. 70.) AH5=S5+86.8+.157*T5*D5+5.*DLOG10(T5*D5)      JMC  621
        IF(T6*D6 .GT. 70.) AH6=S6+86.8+.157*T6*D6+5.*DLOG10(T6*D6)      JMC  622
        MS=(AH6-AH5)/(D6-D5)                                            JMC  623
        IF (KK .EQ. 2) GO TO 25                                         JMC  624
        IF (H5 .LE. 10.) GO TO 30                                       JMC  625
        IF (KK .EQ. 1) GO TO 20                                         JMC  626
   25   MS=MSS                                                          JMC  627
        AH50=AH5                                                        JMC  628
        AH5=AH5S                                                        JMC  629
        D5=D5S                                                          JMC  630
        GO TO 30                                                        JMC  631
   20   DH=0.                                                           JMC  632
        DL1=DLS1*DEXP(-.07*DSQRT(DH/DMAX1(5.0D0,H1E)))                  JMC  633
        DL2=DLS2*DEXP(-.07*DSQRT(DH/DMAX1(5.0D0,H2E)))                  JMC  634
        DL=DL1+DL2                                                      JMC  635
        TE1=(.00065/DLS1)*((DLS1/DL1-1)*DH-3.077*H1E)                   JMC  636
        TE2=(.00065/DLS2)*((DLS2/DL2-1)*DH-3.077*H2E)                   JMC  637
        TE=DMAX1((TE1+TE2),(-DL/A))                                     JMC  638
        T=TE+D/A                                                        JMC  639
        AH5S=AH5                                                        JMC  640
        MSS=MS                                                          JMC  641
        D5S=D5                                                          JMC  642
        GO TO 10                                                        JMC  643
   30   CONTINUE                                                        JMC  644
        RETURN                                                          JMC  645
        END                                                             JMC  646

        SUBROUTINE LOS                                                  JMC  647
C                                                                       JMC  648
CCC     SUBROUTINE TO COMPUTE LINE OF SIGHT ATTENUATION                 JMC  649
C                                                                       JMC  650
        IMPLICIT REAL*8(A-H,O-Z)                                        JMC  651
        COMMON /MM/F,D,NS,A,DH,DHS,S,E,POL,KM                           JMC  652
        COMMON /NR/W,SW3,SW4,SA3,SA4,SAFO,JZ                            JMC  653
        COMMON /MP/ H1E,H2E,H1G,H2G,DLS1,DLS2,DL1,DL2,DL,DLS,TE1,TE2,TE,KLJMC  654
        COMMON /MLDS/AG,AD,AS,ACR,AED,MD,AH50,AH5,D5,MS,AES,DX,H5       JMC  655
        COMMON /ML/ D0,D1,D01,D02,A0,A1,K1,K2,AL,ALS,AOG                JMC  656
        REAL*8 NS,MD,MD0,MS,MSS,MDS,K1,K2,K3,K4,M                       JMC  657
        KM=2                                                            JMC  658
        CALL DIFF                                                       JMC  659
        KM=0                                                            JMC  660
C                                                                       JMC  661
CCC     CALCULATION OF TWO RAY THEORY                                   JMC  662
C                                                                       JMC  663
        D01=.00004*H1E*H2E*F                                            JMC  664
                                                                        JMC  665
```

```
      DO2=DMIN1((-AED/MD),(DL-2.))                                          JMC  666
      IF (AED .GE. 0.) DO=DMIN1(DO1,(.5*DL))                                JMC  667
      IF (AED .LT. 0.) DO=.5*DL                                             JMC  668
      IF (AED .LT. 0. AND. DO2 .GE. DO) DO=DO2                              JMC  669
      D1=DO+.25*(DL-DO)                                                     JMC  670
      IF (D1 .LE. DO) D1=DO+.25*(DLS-DO)                                    JMC  671
      J=0                                                                   JMC  672
      DS=D                                                                  JMC  673
      IF (J .EQ.0) D=DO                                                     JMC  674
   22 DIV=1.                                                                JMC  675
      PSI=DATAN((H1E+H2E)/(1000.*D))                                        JMC  676
    2 DHD=DH*(1.-.8*DEXP(-.02*D))                                           JMC  677
      SH=.78*DHD*DEXP(-.5*DHD**.25)                                         JMC  678
      SP=DSIN(PSI)                                                          JMC  679
      X=18000.*S/E                                                          JMC  680
      P2=(DSQRT((E-DCOS(PSI)*DCOS(PSI))**2.+X*X)+E-DCOS(PSI)*DCOS(PSI))/JMC  681
     C2.                                                                    JMC  682
      P=DSQRT(P2)                                                           JMC  683
      Q=X/(2.*P)                                                            JMC  684
      IF (POL .EQ. 1.) B=(E*E+X*X)/(P2+Q*Q)                                 JMC  685
      IF (POL .EQ. -1.) B=1./(P2+Q*Q)                                       JMC  686
      IF (POL .EQ. 1.) M=2.*(P*E+Q*X)/(P2+Q*Q)                              JMC  687
      IF (POL .EQ. -1.) M=2.*P/(P2+Q*Q)                                     JMC  688
      R2=(1.+B*SP*SP-M*SP)/(1.+B*SP*SP+M*SP)                                JMC  689
      RE=DSQRT(SP)                                                          JMC  690
      SQEXF=DSQRT(R2)*DEXP(-.020958447*F*SH*SP)*DIV                         JMC  691
      IF (SQEXF .GT. .5 .AND. SQEXF .GT. RE) RE=SQEXF                       JMC  692
      C=DATAN(Q/(P+SP))-DATAN(Q/(P-SP))                                     JMC  693
      IF (POL .EQ. -1.) GO TO 40                                            JMC  694
      Y1=(X*SP+Q)/(E*SP+P)                                                  JMC  695
      Y2=(X*SP-Q)/(E*SP-P)                                                  JMC  696
      IF (E*SP .GE. P) C=DATAN(Y1)-DATAN(Y2)+3.141592654                    JMC  697
      IF (E*SP .LT. P .AND. P*SP .GT. .5) C=DATAN(Y1)+DATAN(Y2)             JMC  698
      IF (E*SP .LT. P .AND. P*SP .LE. .5) C=DATAN(Y1)-DATAN(Y2)             JMC  699
   40 IF (J .EQ. 0)                                                         JMC  700
     CA0=-10.*DLOG10(1.+RE*RE-2.*RE*DCOS(.000041917*F*H1E*H2E/DO-C))        JMC  701
      IF (J .EQ. 1) GO TO 3                                                 JMC  702
      D=D1                                                                  JMC  703
      J=1                                                                   JMC  704
      GO TO 22                                                              JMC  705
    3 CONTINUE                                                              JMC  706
      D=DS                                                                  JMC  707
      IF (J .EQ. 1)                                                         JMC  708
     CA1=-10.*DLOG10(1.+RE*RE-2.*RE*DCOS(.000041917*F*H1E*H2E/D1-C))        JMC  709
C                                                                           JMC  710
CC    COMBINATION OF TWO RAY THEORY AND DIFFRACTION                         JMC  711
C                                                                           JMC  712
      ALS=AED+MD*DLS                                                        JMC  713
```

```
      AL=AED+MD*DL                                                                  JMC   714
      DEDO=AED+MD*DO                                                                JMC   715
      DED1=AED+MD*D1                                                                JMC   716
      SA0=A0                                                                        JMC   717
      SA1=A1                                                                        JMC   718
      W=1./(1.+F*DH*.0001)                                                          JMC   719
      A0=DMIN1((W*A0+(1.-W)*DED0),DED0)                                             JMC   720
      A1=DMIN1((W*A1+(1.-W)*DED1),DED1)                                             JMC   721
   10 K2=((ALS-A0)*(D1-D0)-(A1-A0)*(DLS-D0))/((D1-D0)*DLOG10(DLS/D0)-               JMC   722
     C(DLS-D0)*DLOG10(D1/D0))                                                       JMC   723
      K2=DMAX1(K2,0.0D0)                                                            JMC   724
      K1=((ALS-A0)-K2*DLOG10(DLS/D0))/(DLS-D0)                                      JMC   725
      IF (K1 .GT. 0.) GO TO 50                                                      JMC   726
      K1=0.                                                                         JMC   727
      K2=(ALS-A0)/(DLOG10(DLS/D0))                                                  JMC   728
   50 AG=A0+K1*(D-D0)+K2*DLOG10(D/D0)                                               JMC   729
      IF (AG .LT. 0.)  AG=0.                                                        JMC   730
   51 ACG=A0                                                                        JMC   731
   53 ACP=AG                                                                        JMC   732
      RETURN                                                                        JMC   733
      END                                                                           JMC   734

      SUBROUTINE UTPLOT (X  ,Y  ,NDATA,XMAX,XMIN,YMAX,YMIN,KKZ,MODCUR)              JMC   735
      DIMENSION GRID(61,81),XSCALE(5),YSCALE(7)                                     JMC   736
      DIMENSION X  (1),Y  (1)                                                       JMC   737
      INTEGER*2 GRID,BLANK,DOT,XCHAR(4)/1H.,1H+,1H*,1HX/                            JMC   738
      DATA DOT,BLANK/Z4B40,Z4040/                                                   JMC   739
      KDATA=NDATA*KKZ                                                               JMC   740
      IF(MODCUR.GT.1) GO TO 444                                                     JMC   741
C                                                                                   JMC   742
CCC   GRID IS THE MATRIX USED TO PLOT THE POINTS                                    JMC   743
C                                                                                   JMC   744
      IERR=0                                                                        JMC   745
C                                                                                   JMC   746
CCC   CHECKING X AND Y POINTS AND PLOTTING THOSE OUT OF RANGE                       JMC   747
CCC   AT THE MARGIN                                                                 JMC   748
C                                                                                   JMC   749
      DO 30 I=1,KDATA,KKZ                                                           JMC   750
      IF(X(I).GT.XMAX.OR.X(I).LT.XMIN.OR.Y(I).GT.YMAX.OR.Y(I).LT.YMIN)              JMC   751
     1   IERR=IERR+1                                                              JMC   752
      IF(X(I).LE.XMAX) GO TO 205                                                    JMC   753
      X  (I)=XMAX                                                                   JMC   754
      GOTO 210                                                                      JMC   755
  205 IF(X(I).GE.XMIN) GO TO 210                                                    JMC   756
      X  (I)=XMIN                                                                   JMC   757
  210 IF(Y(I).LE.YMAX) GO TO 215                                                    JMC   758
      Y  (I)=YMAX                                                                   JMC   759
```

```
      GOTO 30                                                          JMC   760
  215 IF(Y(I).GE.YMIN) GO TO 30                                        JMC   761
      Y  (I)=YMIN                                                      JMC   762
C                                                                      JMC   763
   30 CONTINUE                                                         JMC   764
C                                                                      JMC   765
CC    PLOTTING X AND Y AXIS , IF NECESSARY                             JMC   766
C                                                                      JMC   767
      JERR=0                                                           JMC   768
      XRANGE=XMAX-XMIN                                                 JMC   769
      YRANGE=YMAX-YMIN                                                 JMC   770
      IF (YRANGE.NE.0.)  GO TO 298                                     JMC   771
      IF(YMIN.EQ.0.) GO TO 889                                         JMC   772
      YMIN=0.                                                          JMC   773
      YRANGE=YMAX                                                      JMC   774
      GO TO 299                                                        JMC   775
  298 IF (XRANGE.NE.0.)  GO TO 299                                     JMC   776
      IF(XMIN.EQ.0.) GO TO 887                                         JMC   777
      XMIN=0.                                                          JMC   778
      XRANGE=XMAX                                                      JMC   779
C                                                                      JMC   780
CC    BLANKING OUT MATRIX-(GRID)                                       JMC   781
C                                                                      JMC   782
  299 DO 300 I=1,61                                                    JMC   783
      DO 301 JJ=1,81                                                   JMC   784
301   GRID(I,JJ)=BLANK                                                 JMC   785
  300 CONTINUE                                                         JMC   786
      IF(XMAX*XMIN.GE.0.) GO TO 222                                    JMC   787
      IYAXIS=80.*(-XMIN)/XRANGE+1.5                                    JMC   788
      DO 40 I=1,61                                                     JMC   789
   40 GRID(I,IYAXIS)=DOT                                               JMC   790
  222 IF(YMAX*YMIN.GE.0.) GO TO 333                                    JMC   791
      IXAXIS=60.*YMAX/YRANGE+1.5                                       JMC   792
      DO 60 I=1,31                                                     JMC   793
   60 GRID(IXAXIS,I)=DOT                                               JMC   794
C                                                                      JMC   795
CC    COMPUTE PROPER SCALE NUMBERS                                     JMC   796
C                                                                      JMC   797
  333 XINCR=XRANGE/4.                                                  JMC   798
      YINCR=YRANGE/6.                                                  JMC   799
      XSCALE(1)=XMAX                                                   JMC   800
      XSCALE(5)=XMIN                                                   JMC   801
      DO 80 I=2,4                                                      JMC   802
      XSCALE(I)=XSCALE(I-1)-XINCR                                      JMC   803
      IF(ABS(XSCALE(I)).LT.1.E-4) XSCALE(I)=0.                         JMC   804
   80 CONTINUE                                                         JMC   805
      YSCALE(1)=YMAX                                                   JMC   806
      YSCALE(7)=YMIN                                                   JMC   807
```

```
      DO 81 I=2,6                                                       JMC  808
      YSCALE(I)=YSCALE(I-1)-YINCR                                       JMC  809
      IF(ABS(YSCALE(I)).LT.1.E-4) YSCALE(I)=0.                          JMC  810
   81 CONTINUE                                                          JMC  811
      DO 85 II=1,2                                                      JMC  812
      JJ=6-II                                                           JMC  813
      XT=XSCALE(JJ)                                                     JMC  814
      XSCALE(JJ)=XSCALE(II)                                             JMC  815
   85 XSCALE(II)=XT                                                     JMC  816
C                                                                       JMC  817
CC                                                                      JMC  818
C     PLACING POINTS IN THEIR PROPER GRID POSITIONS                     JMC  819
C                                                                       JMC  820
  444 IF(MODCUR.LT.2) JSET=0                                            JMC  821
      IF(JERR.GT.0) GO TO 885                                           JMC  822
      JSET=JSET+1                                                       JMC  823
      IF(JSET.GT.4) JSET=1                                              JMC  824
      DO 700 I=1,KDATA,KKZ                                              JMC  825
      IPTX=60.*(YMAX-Y(I))/YRANGE+1.5                                   JMC  826
      IPTY=80.*(X(I)-XMIN)/XRANGE+1.5                                   JMC  827
      IF(IPTX.GT.61.OR.IPTY.GT.81) GO TO 70                             JMC  828
      IF(IPTX.LE.0.OR.IPTY.LE.0)GO TO 70                                JMC  829
      GRID(IPTX,IPTY) = XCHAR(JSET)                                     JMC  830
      GO TO 700                                                         JMC  831
   70 IERR=IERR+1                                                       JMC  832
  700 CONTINUE                                                          JMC  833
C     OUTPUT SECTION WITH GRAPH                                         JMC  834
C                                                                       JMC  835
      IF(MODCUR.EQ.1.OR.MODCUR.EQ.2) RETURN                             JMC  836
      AXR=ABS(XRANGE)                                                   JMC  837
      AYR=ABS(YRANGE)                                                   JMC  838
      IF(AXR.LT.1.E+8.AND.AXR.GE..95) GO TO 400                         JMC  839
      WRITE(6,17) XSCALE                                                JMC  840
   17 FORMAT(12X,1PE10.3,4(10X,E10.3)/15X,'**',8('+*********'),'+**')   JMC  841
      GO TO 401                                                         JMC  842
  400 WRITE(6,117) XSCALE                                               JMC  843
  117 FORMAT( 8X,F11.2,4( 9X,F11.2)/15X,'**',8('+*********'),'+**')     JMC  844
  401 II=1                                                              JMC  845
      DO 101 IK=1,61                                                    JMC  846
      IF(MOD(IK-1,10).NE.0) GO TO 92                                    JMC  847
      IF(AYR.LT.1.E+8.AND.AYR.GE..95) GO TO 404                         JMC  848
      WRITE(6,18) YSCALE(II),(GRID(IK,IX),IX=1,81),YSCALE(II)           JMC  849
   18 FORMAT(3X,1PE10.3,2X,1H+,1X,81A1,1X,1H+,2X,E10.3)                 JMC  850
      GO TO 405                                                         JMC  851
  404 WRITE(6,118) YSCALE(II),(GRID(IK,IX),IX=1,81),YSCALE(II)          JMC  852
  118 FORMAT(2X,F11.2,'  + ',81A1,' +  ',F11.2)                         JMC  853
  405 II=II+1                                                           JMC  854
      GO TO 101                                                         JMC  855
```

```
   92 WRITE(6,19) (GRID(IK,IX),IX=1,81)                                    JMC  856
   19 FORMAT(15X,'* ',81A1,' *')                                           JMC  857
  101 CONTINUE                                                             JMC  858
      IF(AXR.LT.1.E+8.AND.AXR.GE..95) GO TO 402                            JMC  859
      WRITE(6,22) XSCALE                                                   JMC  860
   22 FORMAT(15X,'**',8('+*********'),'+**'/12X,1PE10.3,4(10X,E10.3),//)JMC  861
      GO TO 403                                                            JMC  862
  402 WRITE(6,217) XSCALE                                                  JMC  863
  217 FORMAT(15X,'**',8('+*********'),'+**'/ 8X,F11.2,4( 9X,F11.2),//)  JMC  864
  403 IF(IERR.GT.0) WRITE(6,20) IERR                                       JMC  865
   20  FORMAT(10X 'NUMBER OF POINTS OUT OF RANGE =' ,I4)                   JMC  866
 1000 RETURN                                                               JMC  867
C                                                                          JMC  868
  889 WRITE(6,888)                                                         JMC  869
  888 FORMAT(' ALL Y VALUES=0. CANNOT SETUP PLOT GRID. CHECK MAX & MIN YJMC  870
     1 WHEN MODCUR=0 OR 1.')                                               JMC  871
      JERR=10                                                              JMC  872
      RETURN                                                               JMC  873
  887 WRITE(6,886)                                                         JMC  874
  886 FORMAT(' ALL X VALUES=0. CANNOT SETUP PLOT GRID. CHECK MAX & MIN XJMC  875
     1 WHEN MODCUR=0 OR 1.')                                               JMC  876
      JERR=10                                                              JMC  877
      RETURN                                                               JMC  878
  885 WRITE(6,884)                                                         JMC  879
  884 FORMAT(' GRID NOT SETUP WHEN MODCUR LAST 0 OR 1. NO PLOT UNTIL GRIJMC  880
     1D PROPERLY SETUP')                                                   JMC  881
      RETURN                                                               JMC  882
      END                                                                  JMC  883

      FUNCTION FNA(C)                                                      JMC  884
      IMPLICIT REAL*8(A-H,O-Z)                                             JMC  885
      FNA=6.02+9.11*C-1.27*C*C                                             JMC  886
      RETURN                                                               JMC  887
      END                                                                  JMC  888

      FUNCTION FNB(C)                                                      JMC  889
      IMPLICIT REAL*8(A-H,O-Z)                                             JMC  890
      FNB=12.953+20.*DLOG10(C)                                             JMC  891
      RETURN                                                               JMC  892
      END                                                                  JMC  893
```

```
      FUNCTION FNC(C,F)                                                 JMC   894
      IMPLICIT REAL*8(A-H,O-Z)                                          JMC   895
      FNC=416.4*F**.3333333333*(1.607-C)                                JMC   896
      RETURN                                                            JMC   897
      END                                                               JMC   898

      FUNCTION FND(C,F,E,X)                                             JMC   899
      IMPLICIT REAL*8(A-H,O-Z)                                          JMC   900
      FND=(.36278/(C*F)**.3333333333)*1./((E-1.)**2.+X*X)**.25          JMC   901
      RETURN                                                            JMC   902
      END                                                               JMC   903

      FUNCTION FNE(C,E,X)                                               JMC   904
      IMPLICIT REAL*8(A-H,O-Z)                                          JMC   905
      FNE=C*DSQRT(E*E+X*X)                                              JMC   906
      RETURN                                                            JMC   907
      END                                                               JMC   908
```

INITIAL DISTRIBUTION LIST

		NO. COPIES
1.	DEFENSE DOCUMENTATION CENTER CAMERON STATION ALEXANDRIA, VIRGINIA 22314	2
2.	LIBRARY, CODE 0212 NAVAL POSTGRADUATE SCHOOL MONTEREY, CALIFORNIA 93940	2
3.	ASST. PROFESSOR R.W. ADLER CODE 52AB NAVAL POSTGRADUATE SCHOOL MONTEREY, CALIFORNIA 93940	1
4.	LT. JAMES M. CALLAGHAN 134 MERRIAM STREET WALLA WALLA, WASHINGTON 99362	1

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Naval Postgraduate School
Monterey, California

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

"TROPOPLOT" A Highly Accurate Long Range Computer Program to do Predictions of Tropospheric Radio Transmission Loss Over Irregular Terrain.

4. DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Master's Thesis: June 1973

5. AUTHOR(S) (First name, middle initial, last name)

James M. Callaghan

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1973	45	2

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Postgraduate School Monterey, California 93940

13. ABSTRACT

The object of this study was to develop a highly accurate long range computer program to do predictions of tropospheric radio transmission loss over irregular terrain. The computer program was to be easy to use with an input and output data format such that the user could use the program with little prior instruction. Signal strength calculation capability was also to be included in the program. The basis for the program theory was ESSA Research Report number ERL 67-ITS 67, "Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain."

DD FORM 1 NOV 68 1473 (PAGE 1)

S/N 0101-807-6811

Security Classification

A-31408

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
rediction of Long-Term Median Tropospheric adio Transmission Loss Over Irregular Terrain						
roposperic Scatter						
roposperic Diffraction						
nife Edge Diffraction						
hort and Long Term Fading						
roposperic Communications Systems						

Thesis
C1885 Callaghan
c.2 "TROPOPLOT"; an improved Fortran program for prediction of long-term median tropospheric radio transmission loss over irregular terrain.
143483

Thesis
C1885 Callaghan
c.2 "TROPOPLOT"; an improved Fortran program for prediction of long-term median tropospheric radio transmission loss over irregular terrain.
143483

thesC1885lost
TROPOPLOT :
3 2768 001 01979 7
DUDLEY KNOX LIBRARY